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Using automated image analysis in pig behavioural research: assessment of the influence of enrichment substrate provision on lying behaviour

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Abstract

Visual monitoring of pig behaviours over long periods is very time consuming and has possibility for observer bias. Automated image processing techniques now give the potential to carry out behavioural research in a more effective way. To illustrate this, an image processing technique was applied to identify whether any changes in pig lying behaviour which might be detrimental to welfare resulted from an enrichment provision treatment. The lying patterns of pigs in 6 enriched pens were compared with those of 6 control pens, which had only a suspended enrichment toy, to determine whether daily provision of a rooting material (maize silage) onto a solid plate in the lying area of a fully slatted pen resulted in changed lying time and location. Pigs were monitored by top view CCTV cameras and animals were extracted from their background using image processing algorithms. An ellipse fitting technique was applied to localize each pig and the centre of each fitted ellipse was used in x–y coordinates to find the lying positions after use of an algorithm to remove images in motion preceding the scan. Each pen was virtually subdivided into four zones and the position of each lying pig obtained at 10 minute intervals over a series of 24 h periods. Results of a validation study showed that the image processing technique had an accuracy of

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93-95% when compared to visual scoring. Results from image processing indicated that once daily provision of rooting material significantly changed the diurnal activity pattern ($p<0.001$) and resulted in a modified diurnal pattern of resting location. The study demonstrates that machine vision can be used as a precise and rapid method for quantifying pig lying behaviour for research or practical applications.

Keywords: Enrichment material, Image processing, Lying behaviour, Pig.

1. Introduction

Studies of animal welfare or housing design frequently employ behavioural measures. Visual monitoring of animal behaviour over long periods is very time consuming and has the possibility for subjective interpretation and hence observer bias (Tuyttens et al., 2014). Automated image processing techniques now give the potential to carry out behavioural research in a more effective way (Nasirahmadi et al., 2017a). A number of such techniques have recently been published to capture a range of different behaviours in pigs, for example group activity pattern (Gronskyte et al.,2015 and 2016), locomotory behaviour (Stavrakakis et al., 2015), aggressive interactions (Viazzi et al., 2014; Lee et al., 2016) and mounting behaviour (Nasirahmadi et al., 2016). The automated capture of the lying behaviour of pigs was one of the first techniques to be explored (Shao et al., 1998; Shao and Xin, 2008). More recently, Nasirahmadi et al. (2015 and 2017b) used binary image data and the Delaunay triangulation method for automatic detection and modelling of the group lying pattern of pigs in commercial farm conditions. Despite the existence of these techniques, they have as yet seldom been applied as a tool in behavioural research in pigs.

Access to enrichment materials can improve pig welfare by allowing the animals to express behavioural elements such as feeding and exploring (Bracke et al., 2007; Vanheukelom et al., 2012) and thus reducing the level of aggression (Day et al., 2002) and the biting of tails, ears and other body parts (Van de Weerd et al., 2006; Zonderland et al., 2008; Jensen et al., 2010). European legislation states that pigs must have permanent access to a sufficient quantity of material to enable manipulation behaviours (Commission Directive, 2008/120/EC). Observations of the use of different enrichment materials for pigs have already been made in numerous studies, and it has been shown that substrates in which pigs can root are more attractive than hanging toys (Scott et al., 2006), with edible substrates particularly effective (Jensen et al., 2010). Limited accessibility of rooting materials may lead to aggression and restlessness by causing competition in groups of pigs (Van de Weerd et al., 2006). Therefore, pigs should have enough material and space to allow several pigs to explore and manipulate the material simultaneously (Zwicker et al., 2012). This suggests that distribution onto the flooring would be preferable to a localised substrate dispenser. In pens with solid or partly slatted flooring, enrichment substrates are often placed into the lying area to avoid contamination or passage into the slurry system. However, the provision of enrichment material generally increases activity (e.g. Lyons et al 1995) and this might be deleterious if resting is disrupted in this area of the pen.

Therefore, the aim of this study was to demonstrate the application of image analysis technology, based on an ellipse fitting method, to investigate the lying time and position changes in pens enriched by daily maize silage provision into the lying area compared with control pens which had only a suspended enrichment toy in the activity area.

2. Material and methods

The study was conducted at a commercial pig farm in the UK where a series of rooms each housed 240 finishing pigs. Rooms were 14.35 m wide × 18.60 m long, and subdivided into 12 pens, each 6.75 m wide × 3.10 m long and with a fully slatted floor. A controlled ventilation system maintained a uniform environmental temperature of 20-21°C, which was verified by real time temperature logging at 8 different locations across the room. All pens were equipped with a liquid feeding trough and one drinking nipple. Six pens were selected for the experiment from the 12 pens in a room, each containing 17-20 pigs with group size balanced across treatments. Pigs were of a white commercial breed (Landrace x Large White). In each of two replicates, three pens were equipped with a solid plate (1.0 m × 1.0 m) on the floor in the lying area to allow for delivery of rooting material, while the other three had no plate and only a hanging plastic toy for enrichment, which was present in all pens. The white fluorescent tube lights were switched on during day and night. The experimental phase started after placement of pigs in the pen at approximately 30 kg live weight, and lasted to the end of the fattening period. The enrichment material provided was chopped maize silage (10 kg per day for each pen) and was manually distributed once a day, at approximately 9 AM, onto the floor plate in the experimental pens.

A camera (Sony RF2938, EXview HAD CCD, Board lens 3.6 mm, 90^{o}) was located 4.5 m above the ground with its lens pointing downward and directly above each pen to get a top view (Fig. 1). Cameras were connected via cables to a PC and video images from the cameras were recorded simultaneously for 24 hours during the day and night and stored on the hard disk of the PC using Geovision software (Geovision Inc.) with a frame rate of 30 fps. Using algorithms developed for continuous automated identification of the lying position of the pigs, animal lying positions were obtained at 10 minute intervals on 10 separate days (with 5 day intervals) in two replicate batches of pigs. Each pen was virtually subdivided into four zones in the extracted frame from video files; zone four being near the corridor (designated as the resting area) and zone one against the outer wall (designated as the feeding, activity and dunging area).

Extracted images from video files were analysed using MATLAB® software (the Mathworks Inc., Natick, MA, USA). A background subtraction method was used for both types of pen separately (with and without plate) in order to extract pigs from pen fittings. A global threshold was applied using Otsu's method (Otsu, 1979) and the threshold was used to convert the greyscale image into a binary image. Then, small objects were removed from images by applying a morphological closing operator. In order to localize each pig body as an image, an ellipse fitting algorithm was applied (O'Leary, 2004; Nasirahmadi et al., 2015) and ellipse parameters such as ''major axis length'', ''minor axis length'', ''orientation'' and ''centroid'' were calculated for all fitted ellipses. The centre of the animal can then be used to calculate animal movement and tracking (Xiong and Lauder, 2014). The centroid of each fitted ellipse was used to determine each pig's lying position in the pen in x-y coordinates (Fig. 2). The locomotion detection method which was described by Nasirahmadi et al. (2015) was applied in this study to remove any active pigs and thus process only lying pigs in the images.

To validate the image processing technique 4000 images (10 days × 2 replicates × 200 images per day) were analysed, which is around 25 % of the total number that were used in this study. The number of fitted ellipses (pigs) in each selected image after applying the image processing algorithm was counted and then compared to the number of pigs in that image with reference to manual labelling.

To compare activity levels and lying locations of pigs between the two treatments, using the full dataset from the image processing output, the total proportion of the pigs which were lying, and the proportion of lying pigs in each zone of the pen were analysed using the MIXED procedure in SAS software (Statistical Analysis System; SAS®, 9.4 version for Windows). The model used for all analyses was treatment (rooting plate or control pen), stage of growth (day) and time of day (hour) as fixed effects and, following testing of separate interaction effects and removal of non-significant interactions, included the interaction between treatment and time of day; time of day (hour) was included as the repeated factor.

3. Results

In total, 17280 images were separately analysed (10 days × 144 times in a day × 6 pens × 2 replicates). Results of the validation study on ~25% of the images showed that the average percentage of frames with correct estimation of pigs in the control pen and plate treatment pen using the image processing technique was 95 and 93%, respectively. Incorrect estimations occurred when the algorithm wrongly considered other objects in the pen as pigs or failed to truly localize them. This was most often due to a reduced image quality when flies covered the camera lens with dirt over time.

The percentages of lying pigs in 10 min intervals for the plate and control pens are shown in Fig. 3. The percentage of lying pigs increased during the period of the experiment for both the plate and control pens. Statistical analysis showed that there was a significant effect of day on overall percentage of lying ($p<0.001$; Fig. 3A), with lying time increasing with age, but no difference between the treatments or treatment × day interaction.

As shown in Fig. 3B, between midnight (12 AM) and early morning (6 AM), which was the first feed delivery time, almost all pigs were lying. The lying percentages were reduced from 6 to 9 AM by delivery of fresh feed in both treatments, and further reduced in plate pens because of delivery of rooting material between 8 and 10 AM; on average, around 65% of pigs were lying pigs in these pens while in control pens this value was about 80%. In both treatments, a second activity peak was apparent in the late afternoon and was more pronounced in the control pens. There was a significant treatment × time (hour) interaction indicating that pigs of different treatment had different lying behaviours during the 24 h period ($p<0.001$).

Table 1 shows the results of statistical comparison of the effect of treatment on the lying pattern of grouped pigs. Whilst provision of rooting material had no significant effect on the overall time spent lying by the pigs, it did influence lying location.

The percentage of lying pigs in each zone during the experiment is shown in Fig. 4. In plate pens (Fig. 4A), the proportion of pigs resting in zone 1 decreased more markedly over time, whilst an increasing proportion of pigs chose to lie in zones 2 and 3, adjacent to the plate. In control pens (Fig. 4B), the majority of pigs chose to rest in zone 1, the designated lying area, but as the pigs aged and became larger, the percentage of lying pigs in zone 1 declined and the occurrence of resting in other pen areas increased.

The mean value of the percentage of lying pigs of each zone across the 24 hour period is shown in Fig. 5. Control pens (Fig. 5B) showed a consistent pattern of pen use across the day. In contrast, the pens equipped with plates (Fig. 5A), showed a change in the preferred zones in the hours immediately following substrate provision, when they reduced resting in the region of the plate, reverting back to their original preference once substrate related activity was over.

4. Discussion

Direct vision and video scoring of pig lying behaviours are popular methods in pig welfare monitoring, however these are time consuming methods (Stukenborg et al., 2011). In this study, a computer based approach was chosen to find the lying position and pattern of groups of pigs when providing an enrichment rooting material in a commercial farm situation. Using machine vision techniques, the lying position of pigs in different zones could be automatically calculated. Based on the results, it was identified that some false identification of pigs' lying position happened in the image processing, but this was quantitatively small. It arose because of conditions in the commercial farm, where there was a water pipe in the middle of each pen (2.5 m from the floor) which caused some invisible areas in images. Furthermore, low quality frames gave rise to some mistakes in distinguishing pigs from the plate in pens equipped with the plate. Lastly, as time progressed, soiling by flies dirtied the camera lenses and reduced the visibility of the pens, for which some practical solutions need to be considered.

The general activity patterns of the animals which were recorded using the automated image processing were in accordance with published literature. The proportion of pigs lying showed an increasing trend over time, which is in line with previous findings that lying time increases with age (Ekkel et al., 2003). Furthermore, when looking at the effect of time of day, pigs showed a typical bi-phasic pattern of activity, with morning and later afternoon activity periods as reported elsewhere (Zwicker et al., 2012; Lahrmann et al., 2015). However, the results illustrate that the pattern of pigs' activity during a day was altered by delivery of a rooting substrate, in agreement with Bolhuis et al. (2010) and Fraser (1985). The presentation of an attractive and novel substrate stimulated activity while this remained present, but animals then showed more lying behaviour later in the day, possibly as a consequence of gut fermentation effects of the ingested material (Bolhuis et al., 2010).

Treatment significantly affected the spatial distribution of the lying pigs. Control pigs showed a consistent preference for lying in zone 1, the designated lying area, and later as they increased in size also in zone 4. Although this was the designated dunging area, the choice to lie there might reflect the preference of animals to lie against pen walls rather than in open areas. In contrast, pigs in the plate pens changed their preferred lying area according to the time of day, avoiding the plate zone during the period of substrate-induced activity, but then showing more lying in zones 2 and 3 across the rest of the day. The avoidance of resting in an area of activity is to be expected (Olsen et al., 2001). Since the amount of rooting substrate delivered in this experiment was limited, and it had largely disappeared after 2-3 hours, the effects on focussed activity and inhibition of resting were intense but transient. However, current legislation states that enrichment should be permanently available, raising the question of whether a greater quantity of rooting material lasting throughout the day would cause less intense disruption or give rise to long term relocation of the preferred resting area. The reason for choice of the zones in the vicinity of the plate for subsequent resting in the current experiment is less obvious. It is possible that, since the plate was the only area of solid flooring in the pen, pigs might be attracted to lie there for this reason (Aarnink et al., 1996; Savary et al., 2009), with social facilitation resulting in other pigs subsequently joining this resting group. Further work with different flooring types would be necessary to investigate this issue.

The lying zone which pigs choose is determined by a number of factors, including design of the pen, location of feeder and drinker, and environmental conditions relating to temperature, air velocity and humidity (Spoolder et al., 2012). Lying in the dunging area has negative consequences for hygiene and thermoregulation, and results in dirtier animals (Spoolder et al., 2012). This study illustrates how automatic monitoring of animals can be a useful tool for researchers and for farmers, allowing low cost monitoring of pigs' lying behaviour which can be used as an indication of the way in which environmental conditions affect their welfare and health.

5. Conclusion

In conclusion, it was shown that the developed image processing method using ellipse fitting features was a useful tool to measure the exact location of each pig during lying time and changes in lying patterns in commercial farm conditions. The method used in this study could contribute in the future as an important and economically feasible technique in research and in commercial farms for assessment of livestock welfare in terms of the adequacy of environmental conditions. The provision of a rooting substrate onto a solid plate changed lying patterns; in pens equipped with a plate pigs generally were lying in the middle of the pen around the plate region, whereas in the control pens the region beside pen walls was the most occupied place. This change in lying location preference was influenced by localised activity patterns which might have detrimental consequences for pen hygiene in part slatted pens. Further work on the implications of method of provision of rooting material for enrichment is therefore required.

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Figure captions:

Fig. 1. Top view of the research barn with the enrichment plate and showing zone numbers.

Fig. 2. Different steps used for lying position detection.

Fig. 3. Pig lying frequency during 10 separate days at 5 day intervals over the fattening period (A), and over the 24 hours of the day (B) in pens provided with daily maize silage substrate onto a plate or control pens with a hanging toy enrichment along with standard errors.

Fig. 4. The percentage of lying pigs located in different regions of the pen during 10 separate days at 5 day intervals over the fattening period in pens provided with daily maize silage substrate onto a plate (A) or control pens with a hanging toy enrichment (B) along with standard errors.

Fig. 5. The percentage of lying pigs located in different regions of the pen over the 24 hours of the day in pens provided with daily maize silage substrate onto a plate (A) or control pens with a hanging toy enrichment (B) along with standard errors.

Table 1- The effect of rooting material provision onto a plate in the pen lying area on the total lying time of pigs and the percentage of lying animals in different pen locations determined by automated image processing (see text for definition of zones; SEM= standard error of the mean, df= degree of freedom).

	Treatments (mean value)					
	Plate	Control	SEM	F-Value	df	P-value
Total lying (%)	85.73	84.74	0.871	0.39	92	0.565
Zone 1 (%)	23.68	30.93	0.817	38.23	24	0.003
Zone 2 (%)	24.33	21.83	0.952	3.44	24	0.137
Zone 3 (%)	30.64	22.26	0.594	65.1	24	0.0006
Zone 4 (%)	21.39	25.01	0.866	8.39	24	0.044

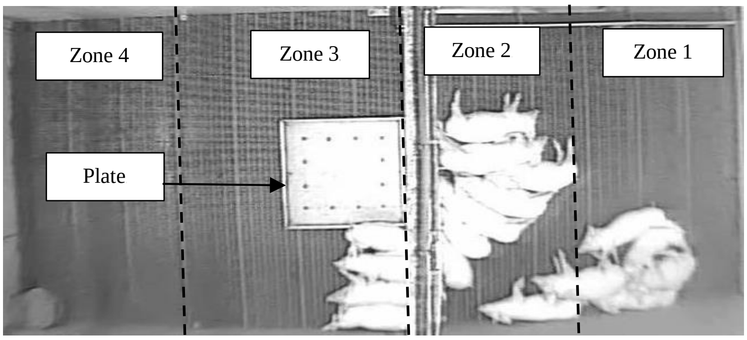

Fig. 1.

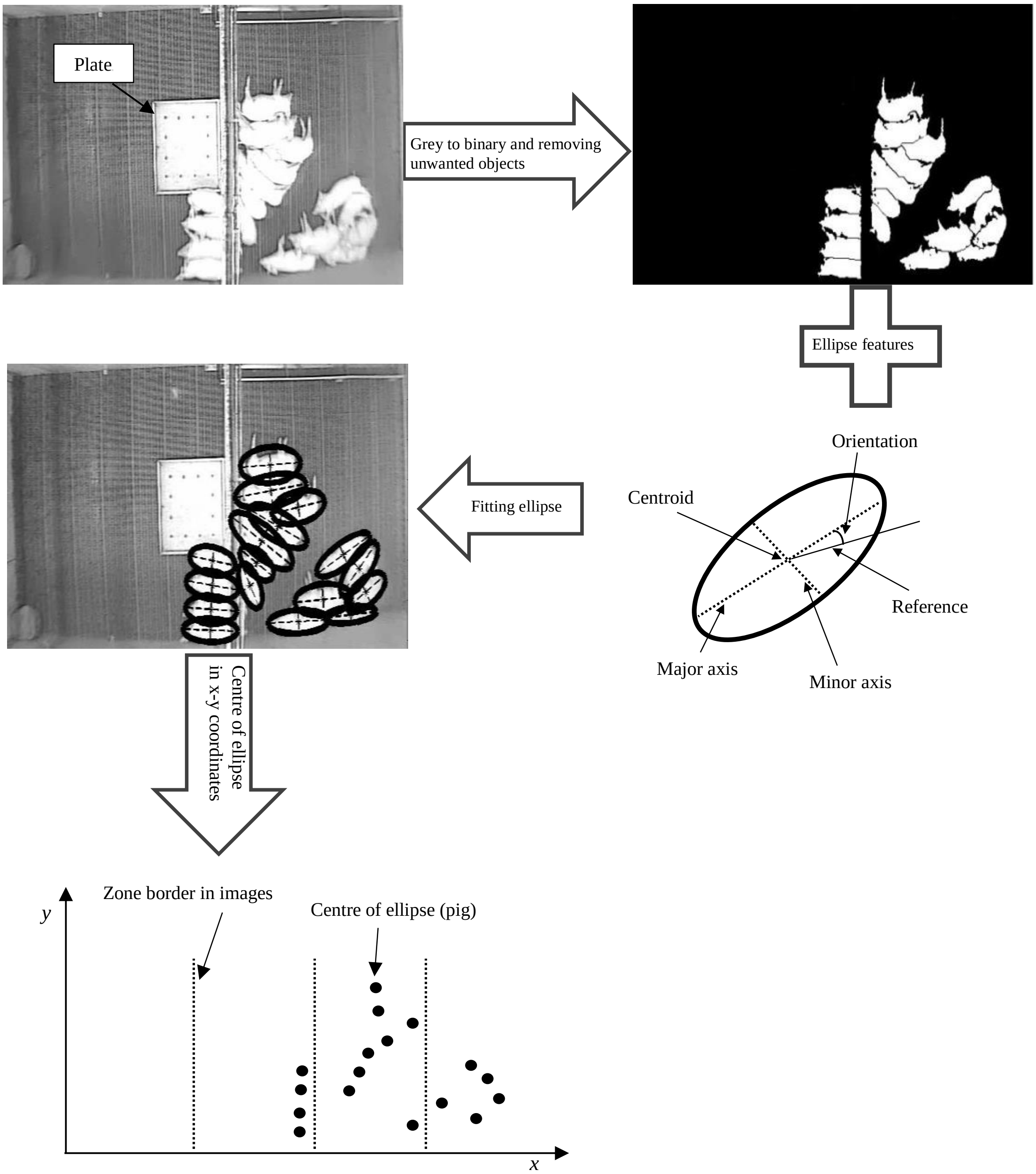
Plate
Grey to binary and removing unwanted objects
Ellipse features
Orientation
Centroid
Fitting ellipse
Reference
Major axis
Minor axis
Centre of ellipse in x-y coordinates
Zone border in images
Centre of ellipse (pig)
y
x

Fig. 2.

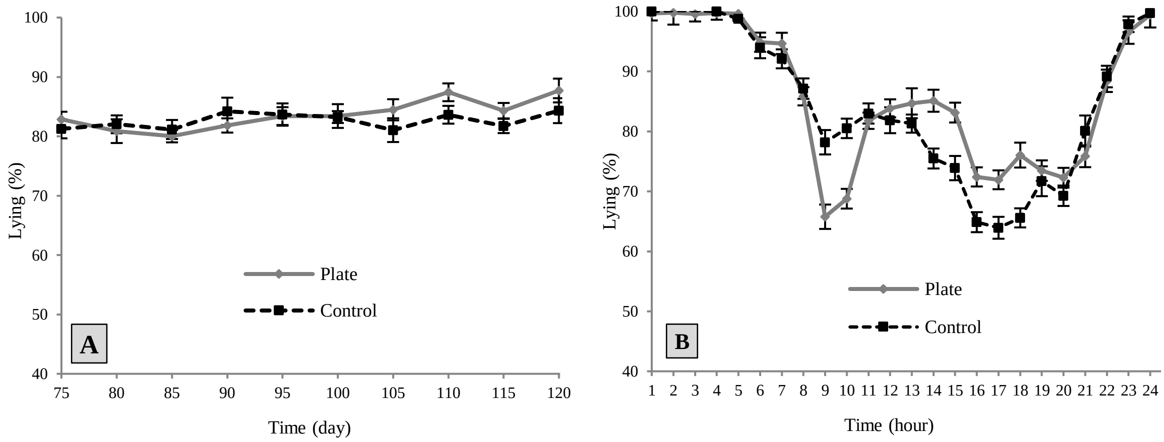

Fig.3.

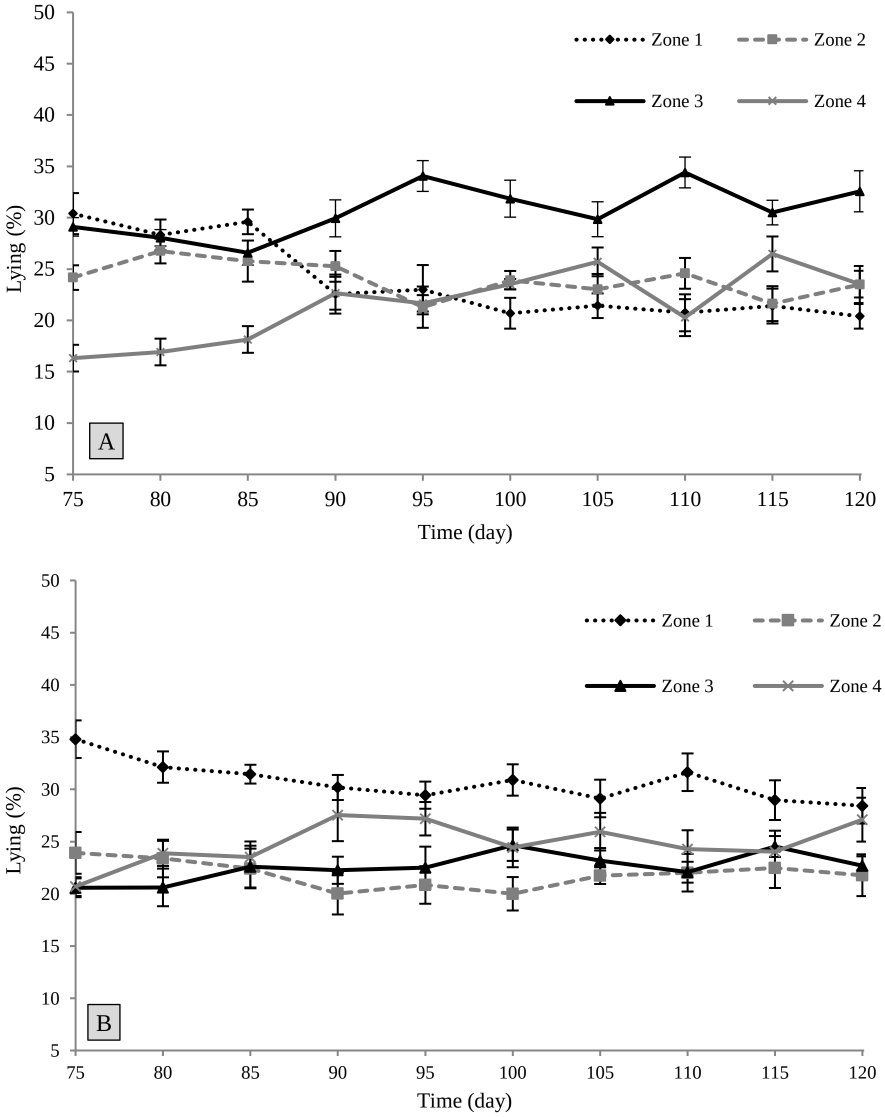
A
Lying (%)
Time (day)
Zone 1
Zone 2
Zone 3
Zone 4
B
Lying (%)
Time (day)
Zone 1
Zone 2
Zone 3
Zone 4

Fig. 4.

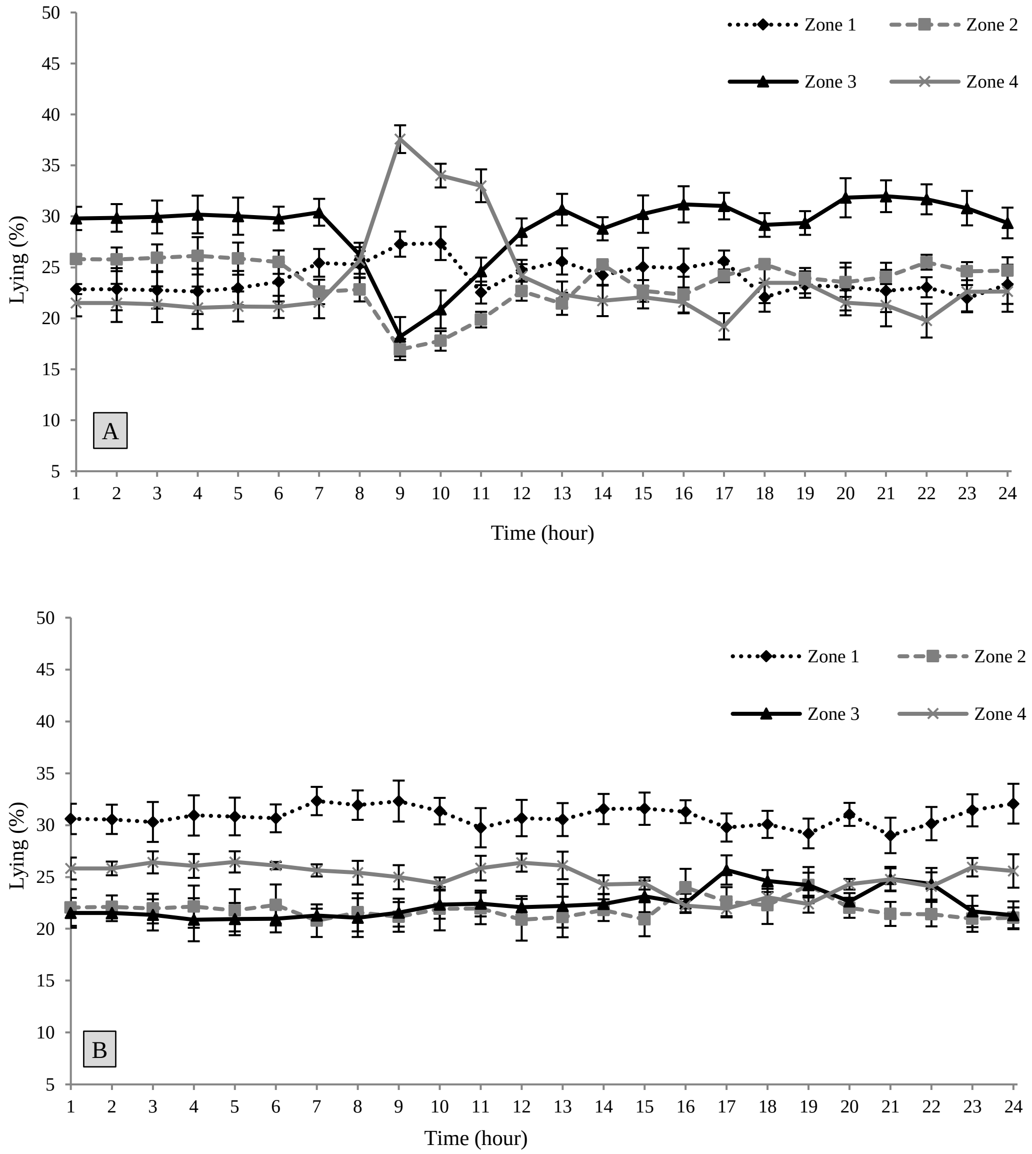
Zone 1
Zone 2
Zone 3
Zone 4
Lying (%)
Time (hour)
A
Zone 1
Zone 2
Zone 3
Zone 4
Lying (%)
Time (hour)
B

Fig. 5.